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One Aspect of Water Resources of the Eighth District

FROM earliest history, the water resources of the region now within the boundaries of the Eighth Federal Reserve District have afforded natural highways. Today these resources have gained new significance as a raw material and may well play a key role in agricultural and industrial growth.

Atmospheric water, one of three principal sources of supply along with underground and surface waters, originates primarily from moist air masses which move inland and bring more moisture to the district than to many other regions of the United States. But much moisture is lost from evaporation and transpiration.

On an annual basis, the district has a larger moisture surplus than do regions occupying vast areas of this country. But, taking seasonal needs into account, the district has considerable areas of moisture deficiency. Thus, ways need to be found to save surpluses and use them in deficiency periods.

Two steps toward helping balance water supply with demand are: (1) to plan a water budget and (2) to put water conserving practices into use.

Supplementary irrigation should be considered as a regular (rather than emergency) practice for many district farms, although there is still much to be learned about the use and conservation of our water resources.

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Survey of Ci

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THE region served by the Federal Reserve Bank of St. Louis was noted for its water resources in earliest history. In 1674, the Mississippi Valley region was said to be composed of "admirable countries and so easy a navigation by beautiful rivers, that from Lake Ontario . . . one could go in a bark to the Gulf of Mexico, having but a single unloading to make . . ."[1] A century and a half prior to this the Spaniards spoke of the wondrous "Rio del Espiritu Santo," now called the Mississippi, and a principal interest in the region was to find if this river afforded a passageway to the Far East.

As the region became settled, population expanded along the waterways. St. Louis became a great fur trading center and later a steamboat terminus for the larger boats that plied the lower Mississippi and the smaller boats used on the shallower upstream channels. Louisville grew at the falls of the Ohio, a major transshipment point of water transportation. Memphis developed on the basis of its facilities to ship cotton by river. Fort Smith increased from an Army post at the head of navigation on the Arkansas to an important trading city. Throughout the present Eighth District area, waterways were the principal highways of the frontier community.

Thus, water was possibly the major resource accounting for the early development of this section of Middle America lying west of the Appalachians. To be sure, the region had other abundant resources, furs, mineral riches, particularly lead, land and climate suitable for both cash and subsistence crops, and timber for construction and fuel, but where there was practically a whole continent to choose from, it was *access* that was most critical. What better access to land in the light of the transportation methods of that time than the broad Mississippi or Ohio, the Illinois and the Wabash or Arkansas and the Tennessee. Despite the hazards of navigation these great fluid roadways were the best available, second only to the seas.

1 Steck, Francis Borgia, THE JOLIET-MARQUETTE EXPEDITION, 1673, Franciscan Fathers, Quincy, Illinois, 1928.

Today these resources have gained new significance as a raw material which will play a key role in agricultural and industrial growth.

Today the situation is radically changed. Beginning with such humble puffs as those of the Pacific Railroad of Missouri, the first west of the Mississippi, which operated the first passenger train from St. Louis to Kansas City in 1865, rail transportation has expanded throughout the district. Motor highways also crisscross district states in every direction. And, overhead all the air has become available for transport. Thus, water in its role as a pathway of commerce, despite the tremendous growth of barge traffic in recent years, has declined in relative significance over the past century.

While water has been forced into a secondary role as a district resource in one case, it has, like a gifted actor, come to the fore in another role which may exceed the significance of its earlier one. This new role for water is that of a raw material, a vital raw material that may spell the difference between expansion or stagnation in industry and agriculture alike. The pressure of population has helped turn the supply of water from one of abundance to one of relative scarcity. Witness the deeper and deeper digging of wells, the turning to "rainmakers," and the building of ever larger reservoirs for city supplies. Furthermore, what was once a supply of good water has too often become a poor one. In effect, the nature as well as adequacy of the present and potential water supply in the Eighth District, considered here, will be one of the leading factors in the district's future economic growth.

Atmospheric water, one of the principal sources of supply along with underground and surface waters, . . .

Too often when the water resources of an area are being described, the analysis is confined to the surface and ground waters. This is only part of the story. Water resources are the result of a revolving process. Water is evaporated from the surface of the sea, brought overland where it may be precipitated as rain or snow. Thence, it runs off into streams or ponds or percolates into underground formations. Some portion is taken into the systems of plants and animals. And the cycle is then completed with a return to the atmosphere by evaporation or transpiration. Or, water may return to the sea through streams, underground seeps or as precipitation. Thus, our report on the water resources of the Eighth District will be divided into three parts, this article dealing only with the first: (1) atmospheric water, (2) ground water, and (3) surface water.

Since the climatic features of the district have already been described to some extent in two earlier articles in the Review,[2] only those considered most pertinent to this analysis will be repeated here. The bulk of this article will deal with effectiveness of precipitation, which was not stressed previously.

. . . originates primarily from moist air masses which move inland . . .

So changeable is the weather of this area from day-to-day, and so erratic has been the variation of rainfall and temperature in the past few years, that many get the impression there is no definite pattern of climatic behavior on which we can rely. This is certainly not the case. The rotation of the earth on its axis, its inclination toward the sun and revolution around the sun are basic factors controlling climate. Other major "controls" are the distribution of the continents and oceans, the behavior of winds and air masses, altitude, mountain barriers, centers of atmospheric pressure, ocean currents and storms. A moment's reflection leads one to realize that most of these controls are relatively fixed or have known behavior insofar as man's time span is concerned. Thus, the same belt of trade winds that Columbus relied on, and the same center of a high-pressure area, known as the "horse latitudes," in which he became becalmed, exist today. The "roaring forties," strong winds prevailing about 60 per cent of the year in 40° S. Latitude that caused sailors to dread rounding the Horn at the tip of South America, blow with equal vigor today, as do their much weaker counterparts in the northern hemisphere, known as the "prevailing westerlies," over Eighth District areas.

The occurrence and nature of the air masses which will ordinarily be experienced over various surface areas of the earth are known. Further, as suggested earlier, the amount of atmospheric moisture received by a region is closely related to the occurrence of moist air masses originating over large water bodies. Even for inland areas, such as this district, the greater share of atmospheric moisture can be traced to oceanic origin. Of course, local phenomena such as the meeting of the warm moist air with a cold air mass or the rising of the air locally causing thunderstorms as in summer, may be immediate causes for the rainfall. But, adequate moisture must be present in the atmosphere. By and large, this moisture has been obtained from the ocean or other large water bodies. Exceptions include the modification of dry polar air after it has traveled long distances over land surfaces, absorbing much moisture.

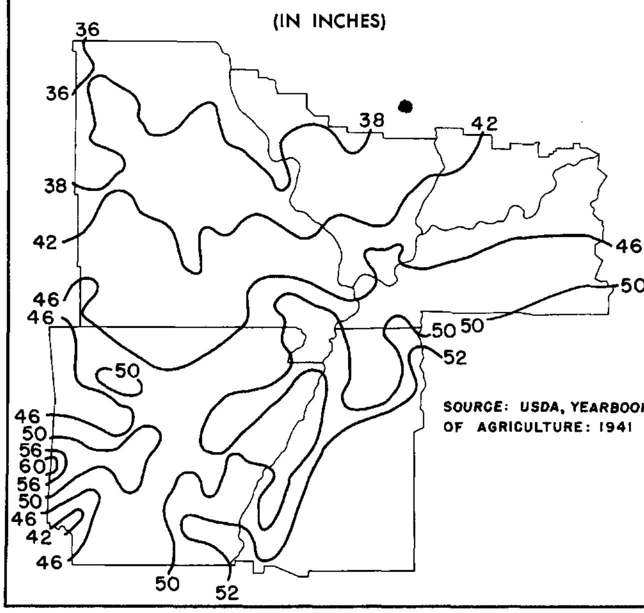
. . . and bring more moisture to the district than to many other regions of the United States.

On balance, the movement of air masses results on the average in considerably heavier annual precipitation in the district than in most of the United States area to the west, but not so much as in certain eastern seaboard and more southern regions. Within district boundaries, the average annual precipitation is heaviest in the southern section, reaching its maximum of over 60 inches in the Ouachita Mountains of western Arkansas, while it is lightest in the northwestern section, averaging only about 36 inches annually in parts of northwestern Missouri (see figure I, below).

But much moisture is lost from evaporation and transpiration.

Thus far we have taken stock of the precipitation deposited on the surface of the district. To complete our analysis of atmospheric moisture we must determine how much of this water is actually available to meet needs. Large amounts are "lost" by evaporation from the earth's surface and transpiration from plants. This process, called "evapotranspiration" is really not a loss in that evaporation adds moisture to the air and has other benefits while transpiration is necessary to the very life of plants. But the amount evaporated and transpired is not usually available to replenish surface and underground supplies in the

FIGURE I
AVERAGE ANNUAL PRECIPITATION
(IN INCHES)



SOURCE: USDA, YEARBOOK OF AGRICULTURE: 1941

2 *Seasonally Adjusted—The Eighth District's Climate*, MONTHLY REVIEW, March 1954. *Some Features of the Economic Geography of the Eighth District*, MONTHLY REVIEW, September 1952.

In these reports on the district's climate it was pointed out that there were both seasonal and cyclical variations from normal (or long-term averages), but that there was no conclusive evidence of a more permanent shift toward a drier or hotter climate.

immediate area. Likewise, these vaporization processes draw down the supply of water in the soil. Obviously, much more precipitation is required to maintain soil moisture adequate to plant needs in a region with heavy evaporation and transpiration than in a region in which the vaporization of moisture by the energy of the sun is relatively light.

The analysis of evaporation relative to precipitation that follows is based on work carried out by Dr. C. W. Thornthwaite, director of the Laboratory of Climatology, Centerton, New Jersey, and a leading expert on climate. Through study of all available data, Thornthwaite has produced a formula that permits the computation of potential evaporation and transpiration (the water loss from the soil that would occur if at no time there is a deficiency of available soil moisture) for any place for which the latitude is known and temperature records are available.[4]

When the potential evaporation so computed is compared with the precipitation and allowance is made for the storage of water in the ground and its subsequent use, periods of moisture deficiency and excess are determined and an understanding of the relative moistness or aridity of a climate is obtained. Such computations have been made for two places representative of conditions in the southern part of the Eighth District, Louisville, Kentucky, and Canton, Mississippi (a few miles south of the district boundary), and the water balances for these stations are shown in figure II. When the soil is full of water, the actual evaporation (the water loss under normally varying soil moisture conditions) and the potential evaporation are the same and all precipitation in excess of the water need is realized as water surplus. In the summer, when precipitation does not equal potential evaporation, the difference is made up in part from soil moisture storage; but as the soil becomes drier, the part not made up is larger. This is the water deficit, the amount by which actual and potential evaporation differ.

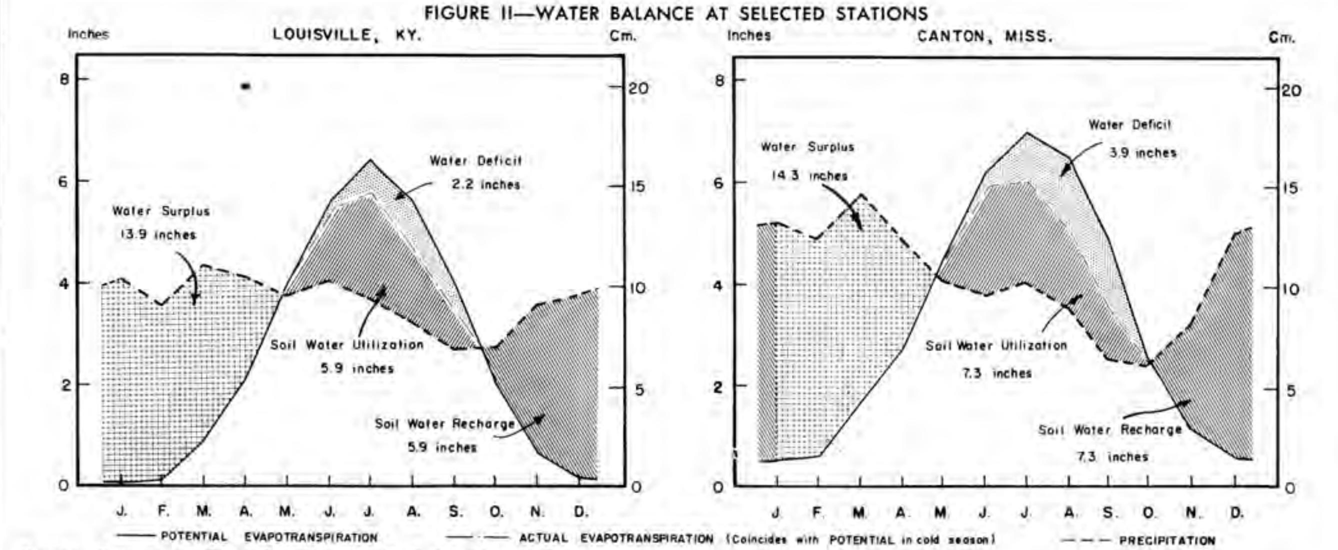
If one compares the moisture surplus and deficit with the water need, it is possible to obtain an index of the relative moistness of a place. When surplus is greater than deficit, the moisture index is positive and the climate is humid or subhumid. When the deficit is greater than the surplus, the moisture index is negative and the climate is arid or semiarid. Computation of the moisture index for Louisville, Kentucky, and Canton, Mississippi, shows that both places experience humid climates. However, because at Canton the relationship of precipitation to potential evaporation results in not only a slightly larger surplus in winter than at Louisville, but also a greater deficit in summer, the moisture index reveals a somewhat less humid climate there than at Louisville.

[4] In this article the word evaporation is used to indicate the combination of evaporation and transpiration, technically known as "evapotranspiration." In tropical rainforest regions almost the entire atmospheric moisture drawn by the energy of the sun from the earth is due to transpiration from the dense canopy of trees which prevents sunlight from reaching the ground. In desert regions, most of the atmospheric moisture drawn from the earth by the sun is due to evaporation from the ground surface. In warm temperate rainy climates, such as that of the district, atmospheric moisture is a resultant of both evaporation and transpiration.

There are only two practical ways of instrumentally measuring evaporation under natural conditions, the "vapor transport" method and the method utilizing soil-filled tanks or evapotranspirometers.

The vapor transport method determines the rate at which air near the ground is mixing with that above it and the difference in water-vapor content at the two levels. Since the turbulence of the air is not constant and the physical measurements required are rather precise, this method cannot at present provide a complete answer to the problem. But it does form a basis for estimates. The other method utilizes a large soil tank containing plants. Water received by precipitation and lost by runoff and retained in the soil is measured, the net difference being the evapotranspiration. Only a few of these stations have been established in the world, none in the Eighth District. See C. W. Thornthwaite, *Evapotranspiration in the Hydrologic Cycle*, The Physical Basis of Water Supply and its Principal Uses, Interior and Insular Affairs Committee, House of Representatives, United States Congress, 1952.

FIGURE II—WATER BALANCE AT SELECTED STATIONS



Source: From unpublished data supplied by C. W. Thornthwaite

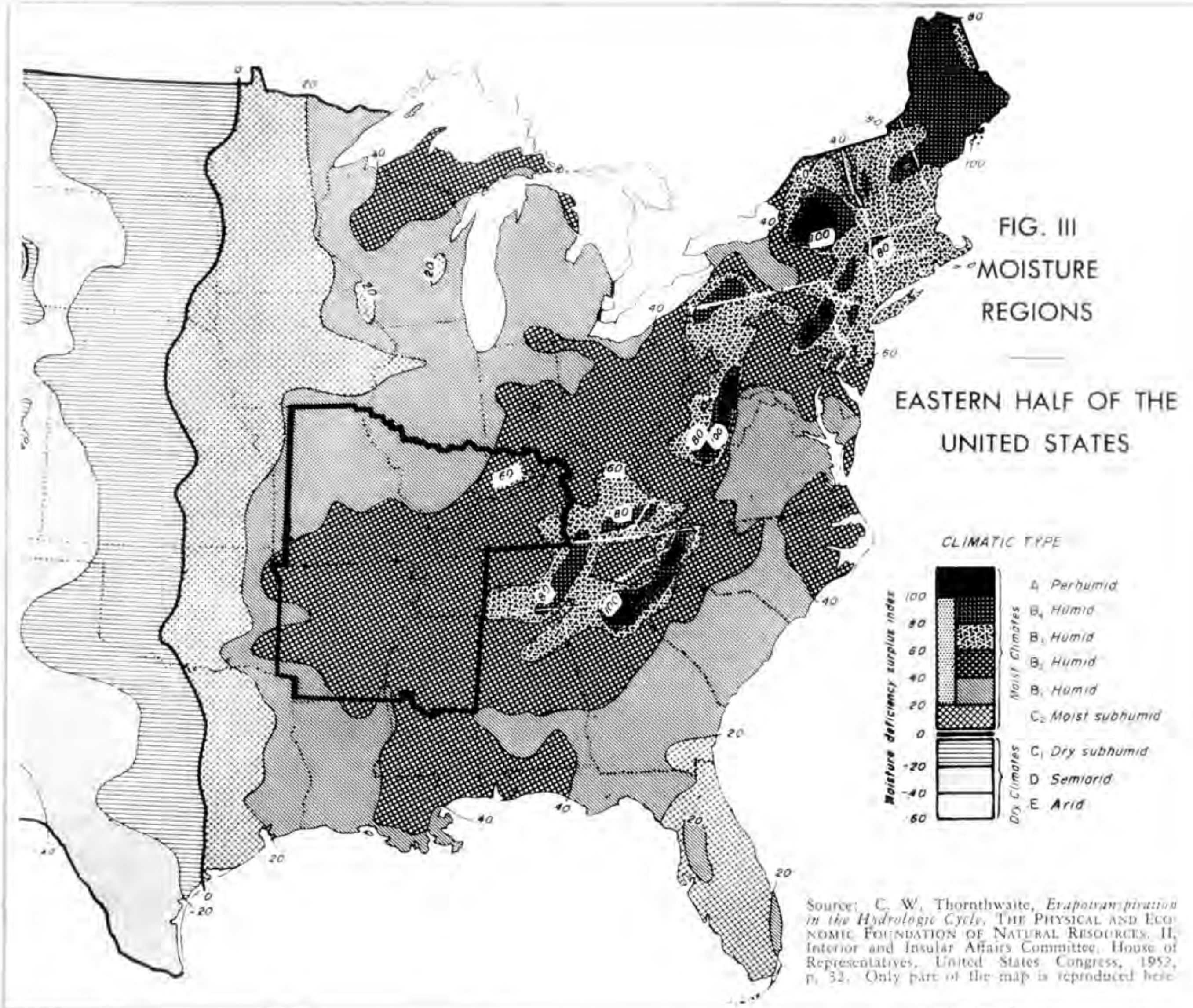


FIG. III
MOISTURE REGIONS

EASTERN HALF OF THE UNITED STATES

Source: C. W. Thornthwaite, *Evapotranspiration in the Hydrologic Cycle*, THE PHYSICAL AND ECONOMIC FOUNDATION OF NATURAL RESOURCES, II, Interior and Insular Affairs Committee, House of Representatives, United States Congress, 1952, p. 32. Only part of the map is reproduced here.

The plotting of values of the moisture index on a map of the United States enables us to get a comparative picture of the moisture situation in the district relative to the rest of the nation. Figure III shows the distribution of moisture regions in the eastern and central parts of this country, according to these indexes.

The index is zero in areas where precipitation is just the same as potential evaporation. Thus at this point the climate, taking the year as a whole, is neither moist nor dry. Where there is a water surplus relative to need, the ratio of this surplus to water need constitutes a moisture index. The map shows that in almost the entire southern part of the district the moisture index is from 40 to 60. Exceptions are southwest Missouri, and small areas in Arkansas and Mississippi. These areas and parts of southern Illinois and all of northern Mississippi have a slightly lower moisture index of 20 to 40. All of the district lies well east of the zero moisture index line. In summary, the map indicates that the district has more soil moisture available annually than a large share of the balance of the land areas in the nation.

The indexes plotted in figures II and III show that the Eighth District has a moisture surplus annually. Deficiencies during part of the year are more than compensated for by surpluses in other parts of the year to provide a positive annual moisture index. However, these surpluses are not directly available to the soil to correct the deficiencies. They run off into

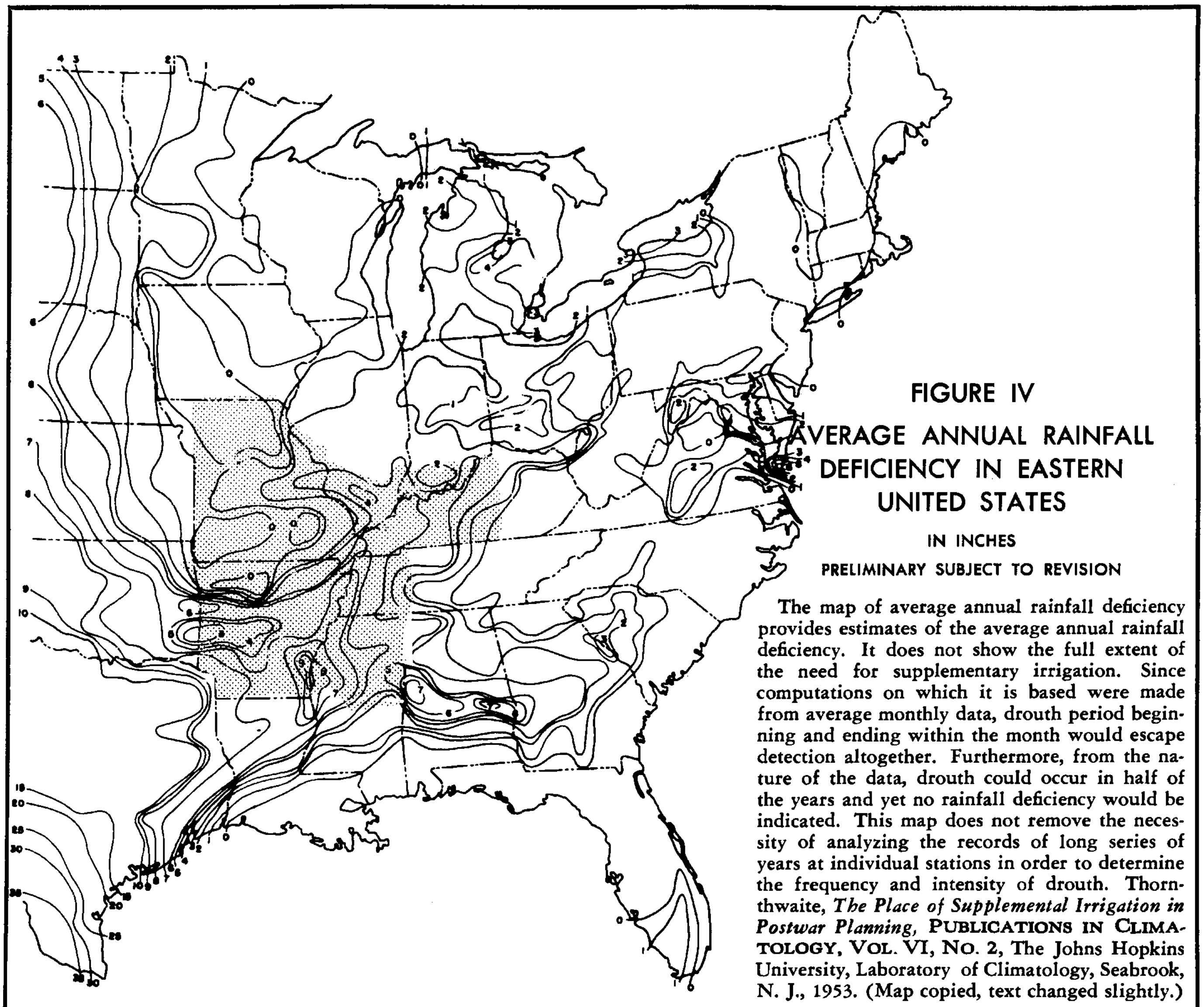


FIGURE IV

AVERAGE ANNUAL RAINFALL DEFICIENCY IN EASTERN UNITED STATES

IN INCHES

PRELIMINARY SUBJECT TO REVISION

The map of average annual rainfall deficiency provides estimates of the average annual rainfall deficiency. It does not show the full extent of the need for supplementary irrigation. Since computations on which it is based were made from average monthly data, drouth period beginning and ending within the month would escape detection altogether. Furthermore, from the nature of the data, drouth could occur in half of the years and yet no rainfall deficiency would be indicated. This map does not remove the necessity of analyzing the records of long series of years at individual stations in order to determine the frequency and intensity of drouth. Thornthwaite, *The Place of Supplemental Irrigation in Postwar Planning*, PUBLICATIONS IN CLIMATOLOGY, VOL. VI, NO. 2, The Johns Hopkins University, Laboratory of Climatology, Seabrook, N. J., 1953. (Map copied, text changed slightly.)

streams or underground supplies. During the period in which deficiencies occur, supplemental irrigation is needed if all the soil moisture that plants could use is to be provided.

The map, figure IV, shows estimates of the number of inches by which precipitation fails to meet needs in deficiency periods, if all the usable soil moisture is to be provided. To arrive at these figures, evaporation (the amount of water actually evaporated into the atmosphere) is compared to soil moisture need (the amount that might have been evaporated and transpired had the soil held a maximum water supply at all times of the year). To clarify further, let us again examine the water balance at Louisville. The annual water need is 31.8 inches of soil moisture. Actual evaporation in the area is nearly 29.6 inches. Therefore, the area needs 2.2 more inches of water in this deficiency period, June through September, if soil moisture is to be maintained at full capacity throughout the year.

The amount of moisture deficiency is an indication of the amount of supplemental irrigation needed, although it does not account for unusual drouth periods. The map shows that, in terms of actual seasonal needs, the district has areas of precipitation deficiency ranging up to 9 inches. Areas of deficiency are generally in the southern part of the district where the heavier evaporation demands more than offset the relatively greater rainfall.

Thus, ways need to be found to save surpluses and use them in deficiency periods.

To sum up the situation regarding the atmospheric moisture in the district, we may say that there is a two-fold problem: moisture deficiency in time of greatest need and moisture surplus when much of the water is not being used. Is there any solution? In addition to the vital need for more basic information, two major steps suggest themselves. (1) We should *plan comprehensive and individual water budgets* on the basis of the information we have and revise them as new facts are obtained. (2) We should *carry out practices designed to achieve better balance in the annual water budgets* both individually and regionally and to harmonize demand with supply in view of long-range climatic prospects.

Two steps toward balancing water supply with demand are: (1) to plan a water budget . . .

Regarding the first suggestion—planning a water budget—considerable help is available. The Weather Bureau provides advance estimates of the hydrologic balance for the coming year. The Bureau also cooperates with agencies in the solution of special problems such as the limits of maximum possible rainfall and snow melt, or critical weather sequences. In our district of net water surplus, a very important part of the Weather Bureau activity is the forecasting of floods. Such forecasts are estimated to have a benefit-to-cost ratio of about thirty to one. Once reservoirs have been built, the Bureau's reports are essential to proper control of the reservoir water pool. Pools from such reservoirs can be released in times of water shortage.

Each farmer in the district should eventually be able to plan his water budget on an annual basis and on a daily basis during the important growing season. To a certain extent, of course, he is forced to do this now by the very demands of nature. He plans crops which take advantage of maximum moisture during their growing period and ripen in the drier season. Or he maintains flooded fields, as for the rice crop, until the harvest.

. . . and (2) to put water conserving practices into use.

The second point, that of carrying out steps to bring water potentials and demand into better balance, is important to stress. This represents the practical application of research and planning. Conservation measures which help prevent excessive runoff are particularly helpful. Maintenance of forests on land unsuited to agriculture, maintenance of winter cover crops, practice of contour plowing and strip cropping are examples of such practices. A study of district forest resources made in 1948 showed that only about 36 per cent of the forest area in district states was being protected against fire. Conservation practices under the 1953 Agricultural Conservation Program were carried out on only about one-half of the farmland in all district states.

Supplementary irrigation should be considered as a regular (rather than emergency) practice for many district farms, . . .

The use of supplementary irrigation offers considerable opportunity in helping reach a better water balance. The idea of irrigation for general field crops is still regarded by many as a practice mostly of concern to farmers in the arid West. At least, that was so until the past few years of drouth. And, if history is any guide, there is reason to believe that, as the drouth fades in memories, so will interest in irrigation in the Midsouth and Midwest district region tend to lag. The fact is, though, that irrigation in this region should not be thought of as just an emergency measure. As this article has brought out, the district has considerable areas that are normally deficient in water supply relative to maximum needs. Today, the problem of irrigation should be further studied in the light of lower costs and new methods. Of course, the costs of alternative ways of increasing yields must always be considered. Also, the physical limitations of irrigation, the problems of available ground and surface waters, must be taken into account.

. . . although there is still much to be learned about the use and conservation of our water resources.

The whole problem of proper use and conservation of water is an extremely complex one about which there is still much to be learned. It is both an extremely local problem, involving consideration of costs and methods by the individual farmer, businessman and housekeeper, and a regional and national problem, for which sound legal and conservation principles must be established and practiced. How wisely we meet this problem of water use and conservation will be a major factor in the future economic growth of the Eighth District.

HARRY B. KIRCHER.